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Creative Knowledge Environments

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The extent to which an individual's (or a group's) creative potential is expressed depends considerably on the environment in which that individual (or group) works. To understand scientific and technological creativity, one needs to analyze the interactions between individuals or groups and their environment. We put forward the concept of a creative knowledge environment (CKE) to examine the environmental influences on individual and group creativity. After reviewing the research literature relevant to creativity using the CKE framework, we identify the main influences promoting creativity at different levels of organization. The framework provides suggestions as to how best to stimulate CKEs to be more creative. The article concludes by identifying issues where further research is needed.

Creativity is vital for the research activities and innovations that are so important in the transition to a more knowledge-intensive economy or the knowledge society (Stehr, 1994). In this article, we argue that the extent to which an individual's or a group's creative potential is expressed in practice depends to a considerable extent on the wider environment in which that individual or group works. Hence, in order to understand scientific and technological creativity, one needs to examine the interactions between individuals or groups and their work environment at different scale levels. To do this, we develop the concept of the *creative knowledge environment* (CKE) and show how this concept can provide a usable systematic framework for obtaining a better understanding of those environmental interactions. If the factors conducive for creativity in the work environment are better understood, we should be better placed to design environments that promote creativity.

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In the innovation literature, there are various concepts that are partly related to CKEs. In particular, proponents of the concept of systems of innovation (e.g., Carlsson, 1997; Edqvist, 1997; Freeman, 1987; Lundvall, 1992; Nelson, 1993) and of the Triple Helix interaction between universities, government, and industry (Etzkowitz & Leydesdorff, 1997; Leydesdorff & Etzkowitz, 1996, 1998) seek to explain how new knowledge and innovations are created. The CKE concept differs from these existing frameworks in that it attempts to identify the specific environmental factors conducive to creativity in research and innovation, and not only what actors are interacting. Furthermore, a CKE can be viewed at several distinct levels of human organization; the innovation systems and Triple Helix models are limited to the organizational or institutional level. Moreover, the CKE concept is more specific than these other frameworks in that it focuses specifically on factors affecting creativity.

Similarly, in the creativity literature over the last two decades, there has been a tendency to move beyond investigations of creative individuals' characteristics and instead to stress the importance of the broader

environment for the production of results that are regarded as creative in that environment (e.g., Amabile & Gryskiewicz, 1989; Csikszentmihalyi, 1999; Damanpour, 1991; Dewett, 2003; Drazin, Glynn, & Kazanjian, 1999; Ford, 1996; Hunter, Bedell, & Mumford, 2005; McCoy & Evans, 2002; Oldham & Cummings, 1996; Stein, 2003; Seitz, 2003; Witt & Beorkrem, 1989; Woodman, Sayer, & Griffin, 1993). The CKE concept is in line with these developments, but differs somewhat from most of them in that it stresses more explicitly and specifically the importance of the various levels and their possible interactions for creativity.

In this article,[1] we define CKEs and review the research literature relevant to CKEs, analyzing what circumstances promote or hinder creativity at different levels of organizations. Next, we distinguish the key components and the different dimensions of CKEs. The CKE framework then enables us to offer some preliminary conclusions with regard to how best to stimulate CKEs to be more creative. Finally, we point to issues on which further research on CKEs is needed.

DEFINITION OF CREATIVE KNOWLEDGE ENVIRONMENTS

In general terms, we, in line with most of the research literature, define creativity as the generation of a product that is not only novel and imaginative but also useful and of good quality.[2] The specific definition we employ here is as follows:

> CKEs are those environments, contexts, and surroundings, the characteristics of which are such that they exert a positive influence on human beings engaged in creative work aiming to produce new knowledge or innovations, whether they work individually or in teams, within a single organization or in collaboration with others.[3]

One can consider CKEs at different scales. At the micro-level is the environment surrounding an individual or small team, where personal interactions and even whether the room where they work has a stimulating color may influence creativity. At the other extreme is the macro-level at which a research institution or a knowledge-intensive firm operates. At this level, a nation, or a group of nations, will have specific institutional arrangements, laws, and regulations, although there are also other research institutions and firms (both competitors and collaborators) that may hinder or promote creative activities. One can thus think of CKEs as a set of nested layers of environmental factors surrounding the unit in which creative activities are undertaken. The unit of analysis can be as small as one person or as large as a multinational firm navigating in a market space to find creative solutions in its search for innovations. In between are other levels of creative units, such as a university department seeking creative ways of performing world-leading research. An important reason for considering not just one scale level is that processes at one level are influenced by properties and events at other levels.[4]

The definition also highlights one essential task for research on CKEs—to identify, classify and understand the relationships between factors that exert a positive (or negative) influence on those engaged in creative work to produce new knowledge or innovations.

WHAT DO WE KNOW ABOUT CKEs?

In this section we review the literature relating specifically to CKEs.[5] In management and psychology, there is an emphasis on studies of research and innovation—i.e., on knowledge creation or exploitation.[6] These can be divided into three main categories—research environment studies, innovation environment studies, and work-team environment studies.

Research Environment Studies

A number of empirical studies have identified factors influencing the performance of research groups in universities, public research organizations, and private research and development (R&D) laboratories. Because successful research performance depends, to a great extent on creativity, these studies are clearly relevant

[1]This article draws on Chapters 1 and 9 by the authors in Hemlin, Allwood, & Martin, 2004.

[2]The need for usefulness and quality in the creative product calls attention to social evaluation processes, while the focus on the product, rather than the creative process, results in less interest in processes that by themselves may be creative but which do not lead to a product evaluated as creative (see also Allwood & Selart, 2001).

[3]We do not attempt here to cover creativity in relation to artistic or cultural activities.

[4]For example, a work team in a firm is influenced not only by its immediate environment, such as the leadership of the team, but also by the culture and goals of the firm and of the sector and country in which it operates.

[5]We carried out a literature search of several social science databases and library catalogues, using search terms such as creativity, innovation, research, knowledge, work, environment, context, situation, group, and team.

[6]Studies in education on suitable conditions for teaching and learning that may influence creativity are excluded here because they concern a specific environment designed for a single purpose (learning); our focus is on general environments for creative human activities which may nevertheless include learning as one of several components.

TABLE 1
Creative Research Environment Characteristics

Clear objectives functioning in a coordinated way for researchers
A primary focus on research
A genuine research culture built up over a period of time
A positive group and/or organizational climate
Group members who participate actively in the leadership of the group's research
A flat and decentralized organizational structure
Internal and external communications that are lively and supporting
Basic resources for staff (adequate time, research funding, research equipment, appropriate premises, and library materials)
Diversity in size, age, and scientific and other experiences of groups and individuals
A high level of motivation and job enjoyment, career structure, promotion, and rewards
Well-managed staff selection
Good individual competencies and characteristics
Excellent and visionary leadership
Quality control (although not in too excessive or intrusive a form)
An institutional base with an established reputation and visibility

Note. This list is derived from Amabile and Gryskiewicz (1989), Andrews (1979), Bland and Ruffin (1992), Ekvall and Ryhammar, (1999), Hollingsworth and Hollingsworth (2000), Martin and Skea (1992), Pelz and Andrews (1966), Stankiewicz (1980), and Witt and Beorkrem (1989), each of whom treats a number of these factors.

to our analysis of CKEs. Their major findings are summarized in Table 1.

The factors in Table 1 operate at different levels and their effects can be summarized under four main conclusions. First, individual researchers and their characteristics are clearly important to research performance. Second, a successful research environment must possess a certain level of resources as well as a participative, collegial management and work style. Third, a degree of breadth in disciplinary backgrounds of group members is conducive for creativity in research. Finally, a creative research environment has specific psychological and organizational characteristics.

Innovation Environment Studies

The characteristics of innovative environments are widely discussed in the management literature. Creative organizations, although often having integrative structures, tend to emphasize diversity, to have multiple structural links internally and externally, to have flexible or permeable boundaries, to have a sense of collective pride and a faith in the talents of individuals, and to emphasize collaboration and teamwork (Kanter, 1996, 1997), characteristics broadly similar to those contributing to CKEs in research.

Kanter (1996) suggested that four stages can often be identified in the innovation process: (a) generation of ideas; (b) coalition-building, during which people are persuaded the creative idea is a good one[7]; (c) translation of the ideas into a product or process; and (d) the diffusion of the innovation. This model is of importance for CKEs because it highlights that different stages in the process may require different environmental conditions. Although the creative activities in the four stages may be partly influenced by similar factors to those found in research environment studies, the process of generating a successful innovation involves certain phases that are not generally relevant to research (e.g., the marketing of products, although there are some similarities between the publication and dissemination phase of research and the marketing phase of commercial products).

A significant conclusion from a review of individual, group, and organizational creativity and innovation is that ''researchers still know surprisingly little about how the creative process works, especially within the context of complex social systems such as formal organizations'' (Woodman et al., 1993, p. 316), the major reason for this being the fragmented approaches that have been adopted. The CKE conceptual framework developed in this article offers a means to overcome that fragmentation.

The concept of *climate* relates to the subjective experience of various aspects of organizations' psychological atmosphere (e.g., Witt & Beorkrem, 1989) or to ''behavior, attitudes and feelings common in the organization'' (Ekvall & Ryhammar, 1999, p. 308), and has been used to characterize the social microenvironment in the organization influencing creativity (see Hunter, Bedell, & Mumford, 2005, for a review). Empirically investigated climate factors found to have a conducive effect on the experienced creativity climate and on creativity include supervisory encouragement, freedom to choose and to work on different assignments, possessing sufficient resources, workload pressure (which may, however, exert a negative influence if it rises above a certain level),[8] and a generally positive social environment with a low level of organizational impediments (Amabile, 1996, 1999; Amabile et al., 1999; Ekvall & Ryhammar, 1999; Stokols, Clitheroe, & Zmuidzinas, 2002). The effect of team climate as a significant influence on innovative capacity in organizations has been investigated by several authors (e.g., Agrell & Gustafson,

[7]There are similarities here with statements made by proponents of 'Actor-Network Theory' in the sociology of science, technology and innovation (e.g., Callon & Law, 1982; Callon et al., 1986; Latour, 1987), who argue that the scientist or innovator must enlist others and enroll their interests if their research or innovation is to prove successful. This has similarities with Csikszentmihalyi (1999) and his notion of the 'field' comprising other actors.

[8]The Yerkes-Dodson law assumes an inverted U-shaped curve, with performance being best when there is a moderate arousal (e.g., Bernstein et al., 1997).

1994; Amabile, 1996; Amabile, Conti, Coon, Lazenby, & Herron, 1996; Amabile & Gryskiewicz, 1989; Anderson & West, 1998). For example, Ekvall and Ryhammar found that 35% of the variance in their creativity index was explained by scores on their creative climate questionnaire.

One multilevel approach to innovative environments (Ford, 1996) takes into account multiple social domains at the micro-, meso- and macro-levels, suggesting individuals draw upon three main resources in undertaking creative actions: (a) sense-making (i.e., how we understand a situation); (b) motivation (including goals, receptivity beliefs or how one foresees the reception of one's actions, capability beliefs or how one expects one's abilities will cope with a given situation, and emotions); and (c) knowledge and ability (including domain-related knowledge, behavioral abilities, and creative-thinking ability). At the organizational level, Ford highlighted the absorptive capacity[9] (the ability to recognize the significance of, and to make fruitful use of, new information) and a predisposition to take risks as two key environmental features affecting creativity and innovation. A meta-analysis of organizational innovation studies concluded that nine organizational factors[10] were conducive for innovation (Damanpour, 1991).

A general aspect of institutions is that they often consolidate actions into established routines (Nelson & Winter, 1982), which may then come to hinder creativity.[11] Likewise, for the research environment, Turner (2000) noted how university departments tend to develop specific interests that may hinder interdisciplinary creativity. In contrast, where there is scope for crossing institutional borders and particularly where this is encouraged, there may well be greater creativity.

A review of literature on leadership behavior conducive to creativity concludes that three components are necessary for the leadership of creative individuals (Mumford, Scott, Gaddis, & Strange, 2002). First, leaders must stimulate idea-generation among individuals and groups. Second, ideas need to be structured, which means emphasizing deadlines and the integration of ideas and projects. Third, leaders should promote ideas by eliciting support from outside. Mumford et al. concluded that the functions of leadership vary over the different stages of creative and innovative processes (see the discussion above).

The relationship between personal and situational factors with regard to creative management styles and leadership was studied by Vinkenburg, Koopman, and Jansen (2001) in a survey of managers in industry and services. They showed that managers exhibiting a certain flexibility with respect to the situational factors making up the environment are likely to prove most successful in terms of generating good performance and creative solutions. This highlights the importance of flexible management styles to CKEs (cf. Mumford et al., 2002).

Work on the spatial dimension of innovation (the geography of innovation) represents one area where attention has focused on the meso- and macro-levels.[12] An important finding in this fast-growing field[13] is that innovative activity tends to be located in clusters (e.g., Florida, 2002b). One reason is that innovation involves a significant element of tacit, embedded, and—to some extent—locally bound (or sticky) skill-type knowledge[14] that is best communicated face-to-face, and this is obviously facilitated by small distances (Asheim & Gertler, 2004).[15] A second reason is that, at least for radical innovations, the circulation and use of knowledge tends to be quite fast and, for this reason, local production and distribution of knowledge is advantageous. Third, to be attractive to talented researchers, a location should offer attractive employment opportunities and environment, including a good salary, a critical mass of other talented researchers and perhaps even a neighborhood characterized by tolerance and cultural diversity (Florida, 2002a, 2003). Other recent studies showing that locations can exert an influence on the creativity of individuals, groups, and organizations in research and innovation are reported by Barnes (2004) and Storper and Venables (2004).

In the same field of research, attention has been paid to the growing amount of work that is project-based in character, where organizational boundaries need to be crossed by people in temporary collaborations pursuing a particular task. This research suggests that the flexibility or fluidity of a knowledge environment may enhance creative efforts (Amin & Cohendet, 2004; DeFillippi & Arthur, 1998; Grahber, 2002; Lam, 2002).

[9]The concept of 'absorptive capacity' was first put forward by Cohen and Levinthal (1989) in relation to firms.

[10]Specialization, functional differentiation, professionalism, centralization, managerial attitude towards change, technical knowledge resources, administrative intensity, slack resources, external and internal communication.

[11]See Leonard-Barton's (1992) discussion of how 'core competences' can be transformed into 'core rigidities.'

[12]One of the first to discuss the 'geography of innovation' was Feldman (1993, 1994).

[13]For reasons of space, we have not attempted to summarize all the literature on the geography of innovation, instead focusing on selected reviews (e.g., Asheim & Gertler, 2004).

[14]The related concept of 'sticky information' was introduced by von Hippel (1994).

[15]There are similarities here with Kuhn's paradigm concept (1970) in its narrow, tacit, 'hands on' sense.

In addition, ICT developments seem to be increasing the fluidity of knowledge environments (Dewett, 2003).

Work-Team Environment Studies

Most empirical studies of work environments have focused at the micro-level on work teams. A review by Unsworth and Parker (2002) suggested that the contextual factors shown in Table 2 are the main ones influencing creativity and innovation. These factors are obviously valid for our analysis of CKEs, although our particular focus on knowledge-creating and knowledge-intensive workplaces means that other characteristics not found in general work places may be important. For instance, the impact of the knowledge of individuals may be more pronounced in CKEs than in general work environments.

A group of studies relates to the influence of task and work design on creativity. According to reviews, there is little evidence of an optimal work group structure, size, or form of leadership for creativity (Anderson, 1992; King & Anderson, 1995; Mumford et al., 2002). Rather, these characteristics appear to be phase- as well as domain-dependent. In other words, these factors differ in importance over time—for example, in the idea-generation phase compared to the implementation phase (cf. Basadur, 2004). Another finding from these reviews is that long-term membership of a group is apparently correlated with a lower degree of innovativeness, which implies that innovation is partly linked to turnover of individuals in teams, consistent with findings from studies of research groups presented above.

A second group of studies, on the social characteristics of work teams, has shown that social interactions are important for creativity (Kasperson, 1978; Lechler, 2001; Sonnentag, 2000; Sparrowe, Liden, Wayne, & Kraimer, 2001; Unsworth & Parker, 2002). For example, a study of work groups in public and private institutions showed that group members central to group advice-sharing activities were more positively rated in terms of individual performance (Sparrowe et al., 2001). Similarly, a study of excellent performers (who are presumably also more creative) in software development revealed that, compared to moderate performers, they "more often regarded cooperation as a useful strategy" and more often participated "in work-related communication and cooperation processes" (Sonnentag, 2000, p. 483).

Social interaction is also important to the success of new ventures. Lechler (2001) analyzed levels of social interaction in entrepreneurial teams (in small knowledge-intensive firms) to identify success factors, finding that high-quality social interaction influences the success of new ventures in terms of innovative capacity. He concluded that, to explain success in relation to entrepreneurial business and innovation, social interactions need to be included as part of a model that also includes team composition and task performance.

On a similar theme, Bouty (2000), in a study of public and private-sector institutions, analyzed individual decision processes in informal exchanges between scientists and across organizational borders. She demonstrated that social capital, as reflected in informal contacts, exerts a strong influence on organizational learning (see also Allwood & Hedelin, 2005), with equitable exchanges seemingly more fruitful than profitable ones. This shows the importance of CKEs that stimulate informal contacts between individuals across organizational borders for the benefit of the organization itself and not just for individuals.

In a survey of employees in a well-established firm, Tierney (1997) measured cognitive style, job satisfaction, and creative efficacy within work groups, and found that "the more innovative the cognitive climate of the work group to which an employee belongs, the lower the level of employee job satisfaction" (p. 840). Members of such innovative groups also report less satisfaction with their coworkers. This suggests that innovators may often be creative loners who are less concerned with building relationships, a finding consistent with studies concerning the personalities of creative researchers (e.g., Taylor & Barron, 1963) but not with findings on the importance of communication in CKEs. This suggests that organizations wishing to foster creativity should monitor the efficiency of communication in innovative groups and compensate for the effects of any dissatisfaction, but without at the same time reducing the creative tensions beneficial for creativity and innovation.

In summary, the literature on the environment for research, innovation, and work teams shows that task and work design as well as social and organizational characteristics at the micro- and meso-levels can have a crucial influence on creativity and innovation. Only a few authors, however, described the influences of the macro-level environment. For example, Simonton (1999) pointed to cultural and political influences on creativity, and Seitz (2003) discussed the negative effects of differential distribution of power and resources (e.g., copyright restrictions and other restraints on

TABLE 2
Contextual Factors Influencing Creativity and Innovation in Work Teams

Task and work design (e.g., degree of autonomy, complexity, stressors such as time pressure, work load, job ambiguity, concentration demands, organizational problems)
Social characteristics (e.g., collegial communication, team-working, leadership)
Organizational characteristics (e.g., climate or culture, human resource practices, organizational design)

Note. Based on Unsworth and Parker (2002).

information access and on action) on creativity in groups, communities, and societies. More specifically, Stein (2003) noted that international creativity trainers should be aware of, and adjust for, differences between the culture in which they were trained and the culture into which they are transferring their ideas.

There are, unfortunately, no simple recipes for promoting creativity by suitably modifying the environment. Nevertheless, we can draw certain conclusions. First, individuals are clearly important in CKEs in relation to both research and innovation, especially in the early phases when ideas are generated. Second, a successful CKE embraces certain management and working styles—where managers promote creativity, where teams have considerable autonomy, and where self-leadership and social interaction are prominent. Third, work teams should encourage diversity among members so that an element of creative tension exists and conformity is not overemphasized. Fourth, distinguishing between the different phases of creative work processes is crucial for understanding CKEs; one phase may require different conditions for creativity than another.

CREATIVE KNOWLEDGE ENVIRONMENTS FRAMEWORK

We have conceived of the environment for creativity in a holistic manner, but as made up of components at different levels. More specifically, we interpret it to include the eight components shown in Table 3. As is clear from this list, knowledge environments depend on a wide range of conditions and circumstances that overlap and interact. A specific CKE represents a unique combination of these various characteristics.

The different scales at which CKEs can be analyzed, although lying on a continuum, may conveniently be grouped into the three categories described earlier: macro (which includes the global, national and inter-organizational levels); meso (research institutions, business companies, regions); and micro (research groups, work teams, individuals). At each level, one can identify environmental factors that support or hinder creativity and innovation.

Two aspects can be distinguished for each of the CKE components in Table 3: the social and the cognitive. Examples of the former are openness to new ideas or innovation, relations between colleagues or organizations, and routines for the upkeep of equipment. Examples of the cognitive aspect are particular bodies of knowledge and skills, or cognitive work style and thinking style (e.g., adopting an experimental or trial-and-error approach). In certain cases, however, the distinction between social and cognitive aspects may be difficult to uphold because they are closely intertwined (the cognitive tends to be shaped by social processes which may, for example, affect motivation; the social is affected by understanding and skills). Of

TABLE 3
Components of Knowledge Environments and Their Characteristics

Components	*Characteristics*
Task characteristics	Short-term/long-term, simple/complex, routine/novel, modularized/integrated
Discipline/field	Natural sciences vs. engineering vs. social sciences vs. humanities, theoretical vs. experimental vs. modeling, basic/applied, single paradigm vs. multiple paradigms vs. preparadigmatic, reductionist/holistic, discipline-based/inter- or multi-disciplinary, influence of epistemic community
Individuals	Knowledge, skills, abilities, cognitive style (e.g., broad/narrow, focused/eclectic), motivation, interests, career plans, values, beliefs, other personality properties (e.g., introvert/extrovert)
Group characteristics	Size, integrated/loosely coupled, inward looking (group think) vs. outward-looking, leadership style, degree of group tension/harmony, heterogeneity/homogeneity of group members, chemistry of personalities in the group, composition of knowledge, skills and abilities, agreed on or contested beliefs or underlying assumptions
General work situation for individuals	Number of different work tasks or projects, features of time available for research (e.g., sparse/abundant, fragmented or concentrated), job ambiguity (total autonomy vs. narrowly defined goals), quality of IT available (including the usability)
Physical environment	Facilities, buildings, architecture, location, climate, equipment
Organization	Income sources, economic situation, organizational structure and culture, reward profile, leadership and managerial style (e.g., controlling/allowing), degree of organizational tension/harmony
Extra-organizational environment	Small/large economy, expanding/decreasing economy, market characteristics (e.g., open/restricted, global/regional, competitive/monopoly), reward profile, information availability (open/closed), job opportunities and mobility, regional, national and cultural characteristics

Note. Derived from Hemlin, Allwood, and Martin (2004, p. 7).

the eight components, two (group characteristics and general work situation for individuals) are more social, and two others (task characteristics and discipline/field) field) are more cognitive; for the others (individuals, physical environment, organization, and extraorganizational environment), it may not be very fruitful to emphasize one or the other aspect.

There is also a subjective experiential side to environments that is important for CKEs. Two approaches can be found in the literature. One (previously discussed) emphasizes the organizational climate: how it is influenced by other variables (such as leadership, workload, and access to resources) and how it influences creativity (e.g., Agrell & Gustafson, 1994; Amabile, 1996, 1999; Amabile & Gryskiewicz, 1989; Amabile, Conti, Coon, Lazenby, & Herron, 1996; Anderson & West, 1998; Ekvall & Ryhammar, 1999; Hunter et al., 2005; Stokols et al., 2002). The other focuses on the historical and local situatedness of subjective meaning (Drazin et al., 1999; Ford, 1996; Weick, 1995), examining how an individual's perception of the reality she encounters is affected by her goals and motivation, which will, to a large extent, then guide her thinking and acting. As a result, the various interpretations that are made of the environment by individuals and groups form an integral part of CKEs. This approach often stresses the negotiated and political aspects of meaning and how such aspects, for example through tensions and crises, may affect creative processes and promote creative outcomes (Amabile & Gryskiewicz, 1989). An important related concept is the tension both between individuals and between the individual and the domain. Tension can be thought of here as some degree of unease or discomfort in a social relationship or some ambiguity towards a knowledge claim. Such tension is not necessarily negative in its effects. By making new aspects salient, for example, it can sometimes be instrumental in bringing about creative changes (e.g., Amabile, 1996, 1999; Hemlin, Allwood, & Martin, 2004; Pelz & Andrews, 1966).

Drazin et al. (1999) also observed that individuals do not possess single work identities; individuals may be part of many occupational contexts and their occupational identity may be as important to them as their membership of specific work units or teams. This may be especially relevant for individuals in nonincremental innovation contexts, where the flow of individuals between organizations may be substantial (Lam, 2002).

Finally, we note that the time dimension is crucial to CKEs—i.e., there is an element of change to be considered when thinking about and planning CKEs. Over time the relevant tasks may alter because their preconditions have changed; disciplines may become more established and developed, individuals may be older and more experienced and have other needs, groups may have become more integrated or more exhausted, and so on.

Towards a Taxonomy

For a given set of CKEs, there will be certain similarities and differences, so it is vital to distinguish the main types of CKEs and to construct a well-formulated taxonomy. In the Triple Helix literature, three broad types of CKEs are distinguished: academe, industry, and government. In order to gain an understanding of CKEs, one needs to be aware of their main differences; for instance, one way in which university CKEs differ from industrial CKEs is the need for academic researchers to publish in scientific journals (i.e., an open science CKE), in contrast with the need for profit in an industrial R&D context (a proprietary R&D CKE). However, we seem to be witnessing the emergence of mixed forms such as Mode 2 hybrids[16] between these broad institutional categories. Within industrial CKEs, publishing may also be important (e.g., in the pharmaceutical sector); however, some universities are becoming more involved in technology transfer, intellectual property, and the exploitation of knowledge, thereby blurring the traditional boundaries between academe and industry.

Moreover, both the university and industrial CKE categories are quite heterogeneous. For example, different types of disciplines may require different CKEs; what makes for a creative knowledge environment in one discipline may be quite different in others, and that required for multi- or interdisciplinary research may be different again. Disciplines have different cognitive and social styles (Becher, 1989; Delamonte, Atkinson, & Parry, 2000; Whitley, 1984). As a result, the nature of innovation in science (Laudan & Laudan, 1989) and the assessment of what is creative may vary, for example, between natural sciences (many of which are characterized by a single, relatively stable paradigm) and social sciences and the humanities (some of which may be multi-paradigmatic with difficulties in communicating between paradigms; while others may be preparadigmatic). Likewise, different types of industrial research contexts may demand different conditions for a CKE to promote creativity and innovation.

The third category in the Triple Helix is the government or public sector. Conditions for these CKEs may again be quite different. Here, knowledge production and exploitation is generally aimed at improved living conditions and public welfare, the development of policies or enhancing the effectiveness of public

[16]Research on 'Mode 2' has analyzed different forms of collaboration between university and industry (Gibbons et al., 1994; Jacob & Hellström, 2000; Nowotny et al., 2001).

institutions. For such CKEs, government policies play a key role. Those policies are based not only on knowledge but also on the prevailing values or ideology regarding the development of society. Knowledge production in such CKEs, therefore, has rather different drivers and functions than in industry and academe. At the same time, the addressing of societal needs is partly dependent on academe and industry producing appropriate knowledge and services. Hence, public CKEs are integrally linked with academic and industrial CKEs (as reflected in the Triple Helix), so the study of CKEs must include analyzing relations between universities, the public sector and industry.

In addition to the institutional type of CKE and the scale level, there is a third aspect or dimension of CKEs to take into account: the stage in the task or problem process. All knowledge-production processes incorporate a number of stages—for example, problem-identification, idea-generation, idea-elaboration, evaluation (including identifying and rejecting poor ideas), and selling (i.e., legitimating and convincing others of the value of) the idea. These stages do not necessarily occur in that order, nor are they always distinct; they may overlap (e.g., the evaluating and selling stages) and be repeated (for instance, there is likely to be an element of evaluation in each of the other phases).

Again, the appropriate conditions for each stage will vary across different institutional types of CKEs. For example, there is a considerable difference at the problem-identification stage between the CKE characteristics of an industrial team aiming to produce a specified service or product and those for an academic group trying to decide what research problem to address. Whereas the problem-identification phase in many university environments is influenced by factors such as disciplinary interests and the agenda of senior researchers and of the wider epistemic community, in industrial CKEs it is heavily shaped by the needs of the company. In the selling (legitimating) phase, the type of legitimation required when attempting to obtain funding for the problems identified will likewise differ in university, public, and industry CKEs. Similarly, the evaluation phase will be conducted according to different criteria. Although in both university and industry CKEs a great many ideas may be rejected during the knowledge-production process,[17] in industry the needs of the company will generally play a far greater role than those of the university in the academic context (although this may be changing as universities seek to procure more external funding).

Together, the institutional type of CKE, the scale level and the stage in the task process can be viewed as constituting the three dimensions of CKEs, as illustrated in Figure 1.

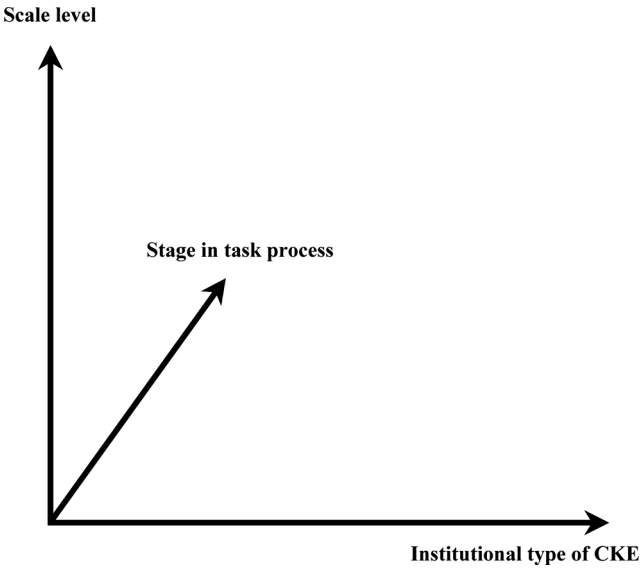

FIGURE 1 The three 'dimensions' of CKEs.

Obviously, the complexity of the eight components and the three dimensions of CKEs make the analysis of CKEs far from easy. However, these analytical distinctions are essential if we are to construct a conceptual framework capable of providing an understanding of the environmental influences on individual and group creativity.

STIMULATING CREATIVE KNOWLEDGE ENVIRONMENTS

Combining the literature reviewed with the CKE framework, we are now in a position to offer some suggestions as to how best to stimulate CKEs to be more creative and innovative (and what is likely to hinder this). We structure this around the eight components of CKEs in Table 3 while taking into account the three dimensions of CKEs shown in Figure 1.

Task Characteristics

Task characteristics such as whether the work is short or long-term, simple or complex, routine or novel, modularized or integrated, clearly have implications for what form of CKE will be most effective. Some tasks are intrinsically more difficult to approach in a creative way; indeed, simple or routine tasks may have a negative effect on creativity. One way to avoid this is to give such tasks (e.g., maintaining equipment) to specialized staff not directly involved in research. It is also important to select staff suited to the task characteristics. For

[17]For a study on the rejection of ideas in an industrial context, see Stevens and Burley (1997).

example, integrated tasks (as opposed to modularized ones) are likely to be better handled by individuals or groups having a broader knowledge base than by a specialist or group of specialists in one field. This is consistent with the heterogeneity thesis discussed in the section on group characteristics below. The task of generating ideas is also different from the tasks of structuring and of promoting ideas and may require different stimuli.

Discipline/Field

Another key aspect of CKEs is the type of knowledge (and skills) relevant for that environment. In an academic CKE, much knowledge production is bound to disciplines or specialties; in industry or the public sector there is generally a more problem-driven approach to knowledge creation. However, the last decade or so has witnessed in academe a large amount of inter-, multi- or trans-disciplinary research focused more on problem-solving than specifically on generating new knowledge (this is linked to the Mode 2 model referred to above).

Interdisciplinarity has often been found to be associated with creativity (e.g., Hollingsworth & Hollingsworth, 2000; Thagard, 2005), and disciplines have sometimes been seen as hindering creativity.[18] Although we largely agree, creativity may not necessarily be related to specialization or to inter- or trans-disciplinarity per se. Instead, such factors as the ability to identify fruitful problems (Allwood, 1997; Allwood & Bärmark, 1999; Arlin, 1990; Kantorovich, 1993) and to conduct both deep and broad analyses of such problems may be more important. Furthermore, different disciplines may demand different types of creative research teams. For example, more restricted associations may be needed in disciplines characterized as normal science in Kuhn's terms (Simonton, 2003).

Knowledge creation depends on being able to draw upon existing knowledge, often from a variety of sources. The promotion of good access to disciplinary, as well as relevant nondisciplinary, knowledge is, therefore, crucial. For micro-level CKEs, the selection of appropriate staff will depend on the nature of the field. In fields with an established paradigm, there is often a formal division of labor between theorists, experimentalists, equipment builders, modelers, and so on, and groups need the full range of such capabilities to be creative. Likewise, in multidisciplinary fields, team members need to have a range of disciplinary backgrounds, and the employing organization has to ensure that the system of incentives is appropriate for stimulating the creative efforts of such a diverse team. At the meso-level, attention must be paid to the organizational structure[19]; if, for example, it is based on traditional disciplines (as in many universities), this may adversely affect the organization's ability to carry out creative multi- or interdisciplinary research (e.g., if interdisciplinary researchers experience difficulties in developing their careers in such environments).

Likewise, at the macro-level, government policies should not result in pressures that constrain interdisciplinary research. For instance, the Research Assessment Exercise in Great Britain may well be constraining the willingness of academics to become involved in multidisciplinary research. Governments need to ensure that their policies do not contain internal contradictions of this type if creativity is to flourish in research and innovation.

Individuals

Individuals are arguably the main components of CKEs; without them, no knowledge would be produced and creativity would not exist. In the CKE framework, creativity is enhanced in environments where individual autonomy is stimulated (at least up to a certain degree, although generally linked to some collective goal), where individuals feel motivated and are rewarded (in some way), where communication with other individuals flows easily and an individual feels secure to express almost any view, where individuals have expert knowledge in at least one domain, and where individuals are left alone to fulfill tasks that are not better done in a group. Individuals' creativity may also be enhanced by contact with researchers in neighboring research areas (Hollingsworth & Hollingsworth, 2000).

Many studies have attempted to identify the crucial personal characteristics of creative persons (see the reviews by Hemlin, 1996; Perkins, 1988; Simonton, 2003; Stoycheva & Lubart, 2001). Amabile (1999) and others have emphasized the importance of intrinsic motivation as a determinant of creativity. Intrinsic motivation is contrasted with extrinsic motivation (e.g., that engendered by payment) and includes such internal stimuli as a strong interest in the subject. Many researchers stress the importance of quite extensive knowledge of the domain if creative action is to take place (e.g., Amabile, 1999; Csikszentmihalyi, 1999; Ford, 1996; Simon, 1965). Amabile (1996) has also pointed out that a degree of practice and learning in relation to creative action is generally necessary for creativity to occur. Other distinguishing features of more

[18]Turner (2000, pp. 50–51) characterizes the formation of disciplines as "a kind of protectionist device."

[19]This links in with the discussion below in the sub-section on group characteristics.

creative persons are a greater openness to experience and change, a higher tolerance for ambiguity, and a greater tendency to investigate conditions and alternatives and not to see conclusions as definitive (i.e., a low need for closure; see Perkins, 1988; Stoycheva and Lubart, 2001). In addition, creative persons often show broad interests, an attraction to complexity, self-confidence, aesthetic sensitivity, and an emphasis on the value of originality and independence, and they tend to reject the narrow and the mediocre and to cherish the general and the fundamental (e.g., Perkins, 1988). Finally, individuals in a happy mood have been found to be more creative than individuals in less happy moods, although there are exceptions (e.g., Bless, 2000; George & Zhou, 2002; Isen, 1987).

Researchers with a good knowledge of their area who change to a new field tend to be more creative because they have access to knowledge, understanding, and ideas that are unusual compared with their colleagues, but which may be relevant in their new field. Unusual knowledge may, for example, stimulate creative metaphorical thinking (e.g., Ziman, 1987).

Group Characteristics

The characteristics of a group—whether it is integrated or loosely coupled, inward- or outward-looking, the leadership style, degree of tension or harmony, and the heterogeneity or homogeneity of group members—are all potential influences on creativity. To take the last of these, the heterogeneity of group members in terms of cognitive and social parameters is generally beneficial (e.g., providing a variety of expertise in different domains). Given that individuals approach the task of knowledge production from a specific limited perspective—a perspective shaped by local conditions (including their disciplinary, institutional, cultural, social, geographical, and motivational situation)—groups including members from different cultural or disciplinary backgrounds tend to be more creative than those whose members share a more homogeneous background.

At the same time, it can be difficult to get researchers from different fields to collaborate successfully (e.g., Ancona & Cadwell, 1992, cited in Blackler, Crump, & McDonald, 1998). More effort is often needed to manage a group of researchers with very different disciplinary backgrounds because of the consequent clash of ideas (Katz & Martin, 1997) and social styles. Hence, the costs associated with managing heterogeneous groups may, on occasion, more than offset the positive effects (Bromme, 2000; Katz & Martin, 1997; Tierney, 1997). This raises the question of what kind of structures and factors hinder the development of interdisciplinary research[20] or the migration of researchers from one field of work to another. Issues here include the extent to which different disciplines may be subject to a territorial imperative, and the varying permeability of disciplinary boundaries to external colonizers (Turner, 2000).

A harmonious social atmosphere does not (as often imagined) necessarily lead to greater creativity. Instead, different cognitive styles that cause some (but not too much) irritation should be tolerated and even encouraged in the light of earlier comments about the beneficial effects of creative tensions. Indeed, a lively and outspoken minority may facilitate group creativity (Wilke & Kaplan, 2001). However, a more fundamental difference in beliefs or underlying assumptions among group members will not be beneficial if this leads to entrenched positions on how to approach a problem or, even worse, on what problems to pursue (Allwood & Bärmark, 1999). Moreover, a tight time-scale for the task might make such a situation more tense and difficult to handle.

The leadership of groups is often crucial in relation to performance including creativity. Leaders with long and wide-ranging experience, who express clear goals, grant autonomy to team-members, and encourage appropriate phase-adapted behaviors, tend to promote more creative research. Regarding the size and structure of workgroups, the form of the task and the stage of the work process may be more important than group characteristics alone. Moreover, as noted above, some group members make better contributions in terms of problem-finding, and others when the emphasis is on problem-solving. Hence, it may be beneficial for the group's performance if changes are made in the composition of the group at different stages (but not to such an extent that this benefit is offset by effects of the resulting loss of continuity, collective memory, morale, and so on).

Collaboration in groups is usually a strong positive contribution to CKEs, but it takes time and effort to develop and manage (Katz & Martin, 1997). If conducted with little clear sense of strategy, or if carried too far, it will leave insufficient time for creativity and knowledge generation. One reason is that creativity can be helped if, in addition to group interaction, time is also allowed for individual reflection. Evidence supporting this comes from research by Diehl and Stroebe (1987) and others (reviewed by Wilke & Kaplan, 2001), showing that one reason for the lower productivity often found when using the brain-storming technique (as opposed to groups of individuals working independently of one another) is that listening to others may cause

[20]These problems are well illustrated by the case study of a large interdisciplinary project reported in Bärmark and Wallén (1980) and Allwood and Bärmark (1999).

group members to forget their own ideas or hinder their individual reflections (see also Dewett, 2003; Paulus & Yang, 2000).

General Work Situation for Individuals

A creative knowledge environment is one where each individual has a number of tasks or projects and where experiences from one domain can exert a positive influence on another (e.g., Simonton, 2003). However, this presupposes that there is enough time for researchers to devote to each task, because severe time constraints are generally not conducive to creativity. Likewise, interaction with other disciplines can be fruitful for creativity; but, as noted above, this can take time and effort to organize, for example, because of differences in culture across disciplines or because of administrative boundaries separating the collaborating organizations (Allwood & Bärmark, 1999; Bromme, 2000).

ICT, databases, and libraries are likely to be conducive to creativity if they provide access to relevant, reliable information required for the tasks at hand (e.g., Dewett, 2003). More direct retrieval of information for a specific purpose is often helpful, but casual browsing with no very specific purpose may also elicit new information, which in turn might contribute to the production of creative knowledge products (although this can be a distraction if taken too far). Novel ways of presenting data might also stimulate creative ideas (e.g., Chen, 1999). Yet the information explosion made possible by the Internet and the Worldwide Web may, at times, be more of a hindrance in relation to creativity because of the risks of unreliable information and constant interruptions from emails. One important issue in the knowledge management literature[21] (e.g., Fuller, 2002; Hedelin & Allwood, 2002; Nonaka & Takeuchi, 1995; Von Krogh, Ichijo, & Nonaka, 2000) is whether ICTs are advantageous to companies in organizing routines for handling knowledge creatively in the innovation process.[22] Some software, for example, gives direct support for generating creative ideas (Allwood & Kalén, 1994; Dewett, 2003).[23]

[21]For a well informed critique of how knowledge is treated in much of this literature, see Cowan et al. (2000).

[22]One example of a rather mechanical approach to knowledge management is given by Peters (1993), who describes three different ICT systems used by the consultants, McKinsey, to improve knowledge management.

[23]At a more general level, there may be potential lessons from the active research area on Computer-Supported Cooperative Work (CSCW) (see, e.g., articles in the journal of the same name).

Physical Environment

The physical environment almost certainly affects the creativity of individuals and groups, but maybe less directly and strongly than some of the other factors discussed here. In particular, facilities making it easier for individuals to contact one another when needed are likely to be beneficial to creativity. Yet individuals also need facilities that offer solitude, where creative thoughts and ideas can be nurtured, and where reflections on other people's ideas can be arrived at. These two functions of providing space both for meeting others and for reflection are basic to creativity. A study of students suggests that natural materials, complexity of visual details in the environment, windows, and avoidance of cool colors and of manufactured or composite surface materials may stimulate creative performance (McCoy & Evans, 2002). However, further treatment of this topic falls outside the scope of this article.

Organization

Organizations frequently assert that they are creative—that they have a creative culture or climate. Measures of subjectively experienced climates have been found to be associated with creative performance (e.g., Amabile & Gryskiewicz, 1989; Ekvall & Ryhammar, 1999; Witt & Beorkrem, 1989). One basic element in an organization is provision of adequate funding and other resources needed for creativity. Also important are organizational structures; these generally need to be flat to promote knowledge management and innovation in firms, as well as in academic departments and research groups (cf. Damanpour, 1991). This links in with work by Dougherty (1996), who analyzed organizational creativity in terms of four dichotomies or tensions (internal vs. external, old vs. new, top-down vs. bottom-up, and responsibility vs. freedom) that need to be balanced if an organization is to be creative. In Dougherty's view, the most difficult is the last of these, which traditionally is addressed by careful staff selection and by establishing an organizational culture that stresses creativity. This is very much a leadership task, something discussed further below. External rewards are generally given somewhat less emphasis in the literature on creativity than personal or intrinsic motivation (Amabile, 1999). A supportive (but intellectually demanding) climate where individuals express their appreciation to others for their creative efforts is likely to be beneficial for creativity (Mumford & Gustafson, 1988).

The leadership of organizations is responsible for providing frames and rules (along with a wider culture) that enable individuals and groups to be creative. If the leadership promotes a sense of trust, this may stimulate creativity (e.g., with less time being spent worrying about losing one's job or dealing with personal conflicts).

Hence, a certain degree of employment security is good for creativity but, again if taken too far, staff may not be stretched to exert themselves. Conversely, researchers with only fixed-term contracts may be driven by insecurity to aspire to greater efforts in pursuit of creativity. However, if the sense of insecurity is too pervasive, this will have a demotivating effect on morale and creativity, and researchers in such a situation may only strive for short-term goals. Here, as elsewhere, the leaders of groups engaged in research or innovation need to wrestle with the dilemma of how to achieve the most effective balance between various extrinsic and intrinsic tensions.

In line with the CKE concept, research also points to interactions between organizational properties and characteristics of individual staff members. For example, staff with creativity-relevant characteristics who were working on complex, challenging jobs and supervised by supportive and noncontrolling managers showed creative performance, yet staff without creative characteristics were not very creative when carrying out the same tasks under the same managerial style (Oldham & Cummings, 1996).

Extra-Organizational Environment

An organization's creative potential is linked to external events and structures at various levels. For example, researchers in developing countries, because of a lack of resources, may be forced to depend partly on the creative efforts of those in developed nations. As a result, they may be either stimulated or hindered in developing their own creative potential. Apart from the level of a nation's economic development, the evidence suggests that a general openness in society and the free exchange of information are beneficial to creativity. Linked to this is the greater range of job opportunities and voluntary mobility of personnel to be found in more open societies, factors again likely to enhance creativity, and especially nonincremental innovation (Lam, 2002). And in the world of private companies, markets clearly play a vital role for innovations, with the ever-present forces of competition encouraging firms to seek out creative responses to new demands and market opportunities. At the global level, differences in resources and influence may create constraints on the creativity of actors placed in less advantageous situations and hence on the global creative output (Seitz, 2003).

Future Research Agenda

Research on CKEs is at an early stage. For example, although previous studies have helped us understand how the conditions for CKEs are shaped in different contexts, research is needed that evaluates, more systematically, the effects on creativity of different specific constellations of the factors identified here as making up CKEs. This is no easy task. One reason is that it is not clear when, and with respect to what criteria, creativity is to be evaluated; should it be with respect to the potential creativity of research ideas, or at the end of the knowledge-generation process, or after the wider social world has had an opportunity to react to the knowledge product? Likewise, should the judgments of an ad hoc expert panel, for example, or the number of citations in research journals, or the sales figures of a resulting innovation, or estimates of its social impact be used as evaluation criteria? One interesting avenue of research along these lines would consist of longitudinal studies of a CKE over time to analyze how creativity changed in response to changes in the CKE.

Second, more research on different types of CKEs is required. Besides the three basic forms of CKE identified in the Triple Helix literature (academe, industry, and government), other categories may be identified on the basis of typologies of organizations or industrial sectors (see, e.g., Koopman & Pool, 1991). Another example is the distinction between CKEs in developed and developing countries, where we need to improve our understanding of the characteristics of CKEs in different types of developing countries. Linked to this is further research on differences between CKEs in different cultures (such as the work by Triandis, 1994, and Oyserman, Coon, & Kemmelmeier, 2002, comparing individualistic and collectivist cultures).

A third area of research relates to the question of what specific processes promote creativity, and how effective they are. For example, in what circumstances, and to what extent, do shorter or longer visits to other research centers promote creativity? How far does participating in different types of research conferences promote creativity, and how close or distant to one's own specialty should the conference be to best enhance creativity? What is the optimum balance between group interaction and individual reflection to promote creativity? How do the answers to such questions depend on the phase in the knowledge production process, the type of research task or the institutional type of CKE? One topical issue is the question of how best to stimulate individuals and smaller groups into creative action. This includes analyzing the extent to which certain personality characteristics are compatible in a particular type of CKE, how to select the best individuals for a specific CKE, how to enhance creativity in groups, and what type of leadership is required.

A fourth area for further research relates to creative tension, a concept currently suffering from a certain vagueness or ambiguity. Future work should try to

[24]For an example in the field of psychology, see Kim (1995). For a more general description of the conditions for research in developing countries, see Adair (1995).

bring more clarity to the understanding of the concept, and to analyze the processes associated with different types of situations denoted by the various terms making up different forms of creative tensions. In addition, the contribution of creative tensions in different types of CKEs and at different stages of the knowledge-production or innovation process needs to be better understood.

Last, there is fruitful research to be done following up our notion of different levels of CKEs being nested within one another. How do different CKEs interact at different levels (Hackman, 2003)? What government policies are most effective in stimulating different types of CKEs at the meso- and micro-level, and for ensuring those policies are properly integrated to create a well functioning national (or regional) innovation system?

In conclusion, we have developed the concept of CKEs and shown the potential power of the CKE conceptual framework in obtaining a better understanding of creativity in relation to knowledge and innovation, and of the factors likely to stimulate this. However, as this final section makes clear, more research is needed before we are in a position to reliably construct management strategies and government policies that will bring about a significant improvement in our creative endeavors.

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